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TECHNICAL REPORT  
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BIBLIOGRAPHY ON ATMOSPHERIC (CYCLIC) SEA SALTS

by

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## FOREWORD

Designers of military equipment have long been aware of the corrosive effects of salt particles on exposed metals. Salt spray and salt water immersion tests are frequently used to study and determine the resistance of metals and other materials to corrosion by salt. The primary source of atmospheric salt is the ocean. Nevertheless, a few scientists have been aware since the middle of the last century that corrosion due to sea-salts is not confined to areas near the oceans but occurs inland over every part of continental landmasses. Salt particles which are jettied into the air from bursting bubbles on the ocean surface are swept inland by every importation of maritime air and subsequently deposited in rain or snow or as dry salt particles on land surfaces far from oceanic areas. Designers of equipment have been slow to take this into account. Preventive measures for salt corrosion are therefore frequently overlooked in design specifications for equipment and materials to be used at inland installations.

This bibliography of atmospheric (cyclic) sea-salts is designed to bring to the attention of engineers source references on all phases of the sea-salt cycle, particularly those referring to sea-salt distribution and to rates of salt deposition on land. It has been prepared as an ancillary contribution to an In-house Laboratory Independent Research (ILIR) Project on Atmospheric Contaminants.

The writer is indebted to a number of people for assistance in translating titles, obtaining data and publications from all parts of the world, particularly: William L. Molo, National Oceanographic Data Center; Bianca D'Atri, Patricia Olstead, Margaret Comick, Eugene Peary and Robert McDonald, Technical Library, U.S. Army Natick Laboratories.

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## ABSTRACT

This bibliography provides more than 600 references covering all phases of the sea-salt cycle: the origin of the particles in salt lakes, playas, and oceans, the processes by which the salt particles are jettied into the air from sea and lake surfaces by bursting bubbles, their transport inland over the continental landmasses, their impingement, incrustment, and fallout either as dry salt particles or in various forms of precipitation and their eventual return in rivers to the sea. Selected references are also included on the historic development of the subject, methods of chemical analysis, and techniques of instrumentation and experimental research leading to the formulation of current theories and postulations.

An Index to Subjects is included so that the reader may quickly locate references pertaining to his immediate interest. Most of the current meteorological and geophysical journals as well as obscure sources of world-wide scope have been used in this compilation.

## BIBLIOGRAPHY ON ATMOSPHERIC (CYCLIC) SEA-SALTS

### INTRODUCTION

Atmospheric pollution is one of the world's foremost problems. Sea-salts are one of the natural pollutants that contribute to this problem. Sea-salts are an enigma in that they play a dual role in being both beneficial and destructive. Sea-salts are an essential component of atmospheric processes in that they serve as nuclei around which raindrops form. Under certain environmental conditions they are also highly corrosive to certain metals and therefore must be considered in the design of any material exposed to the atmosphere.

This bibliography has been prepared as an ancillary contribution to an In-house Laboratory Independent Research (ILIR) Project on Atmospheric Contaminants. It consists primarily of a collection of references selected from material assembled as a basis for a preliminary report on atmospheric sea-salt design criteria areas published by the writer in 1965,\* and as background for a desert aerosol project in 1969.

Nearly all of the articles cited have been reviewed by the writer and are known to contain data pertinent to practically every phase of the sea-salt cycle. They therefore merit publication as a selected bibliography for those researchers requiring more detail than that presented in the original paper.

The bibliography is primarily intended for design and test engineers engaged in protecting equipment and installations from corrosion due to atmospheric sea-salt fallout, but it will also be valuable to students concerned with the role of sea-salt particles in the formation of giant condensation nuclei in the atmosphere.

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\*Brierly, William B. Atmosphere Sea-Salts Design Criteria Areas. Journal of Environmental Sciences, 8, 5, 15-23, October 1965.

The bibliography provides comprehensive reference to all phases of the sea-salt cycle: the nature of the sources of the particles in salt lakes, playas, or the oceans, the processes by which sea-salt particles are jettied into the air by bursting bubbles, their transport inland over the continental landmasses, their impingement, incrustment or fallout either as dry salt particles or in solid or liquid precipitation and their eventual return to the sea in river waters. Articles cited also note the recycling of salt particles into the atmosphere from windblown saline soil and encrustations from the surfaces of arid areas. Selected references are also included which present the historic development of the subject; on methods of chemical analysis; and those techniques of instrumentation and experimental research which have led to the formulation of current theories and postulations.

An Index to Subjects is located at the end of the Bibliography to facilitate locating references pertaining to the readers immediate interest.

References are entered alphabetically by author. Where there is more than one reference by the same author, they are listed in chronological order. Citations are given in the language of publication followed in some cases by a free translation in English. Cyrillic letters have been transliterated into English equivalents. Japanese titles are given in English.

Some of the references which have been taken from other reference listings are not cited according to standard bibliographic techniques; they are included in this bibliography despite their incompleteness because they may provide leads to other more useful sources. Corrections or additions for future revisions will be appreciated.

Many journals and other sources have been used in the preparation of this bibliography. Several of them merit special mention because pertinent articles will continue to appear in them or by them. They are:

Meteorological and Geostrophysical Abstracts: American Meteorological Society, Boston, Mass.

Tellus, a quarterly journal of geophysics published mainly in English by the Swedish Geophysical Society, Stockholm.

The Quarterly Journal of the Royal Meteorological Society, London

Bulletin of the American Meteorological Society, Boston, Mass.

Indian Journal of Meteorology and Geophysics, Delhi

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35	54	85	97	179	276	599
47	59	88	111	180	279	600
50	65	89	135	188	368	601

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6	32	51	85	97	120	124	166	186	194	214
8	38	52	88	107	121	143	167	187	195	215
13	39	54	89	114	122	164	179	188	198	217
25	43	68	94	115	123	165	180	193	199	218
242	280	303	314	333	355	390	408	422	436	471
244	294	304	315	334	357	391	410	426	437	472
257	299	305	320	335	381	394	414	428	444	473
268	302	313	322	347	389	407	415	435	461	483
484	528	573	590	605						
500	535	577	591	607						
501	538	582	592							
527	540	588	599							

### b. As Aerosols

7	36	80	125	194	236	269	273	283	335	416
11	50	111	170	197	249	270	274	290	336	470
25	55	112	171	198	252	271	278	294	377	520
35	69	124	181	229	255	272	282	307	378	529
551										
562										
595										

### c. In Clouds

6	124	247	335	394	417	483
70	217	282	347	407	429	499
72	245	300	359	411	431	540
110	246	322	360	413	479	578

\*Numbers refer to the references cited in the bibliography.

d. In Fog

38	93	245	301	396
39	94	247	316	407
67	113	298	318	413
70	159	300	374	441

e. Chemical Composition of Air/Precipitation

20	33	60	75	82	91	95	117	128	134	142
24	34	61	76	83	92	96	118	129	138	145
28	43	65	80	86	93	97	119	130	140	146
30	58	67	81	90	94	112	127	133	141	147
148	163	177	185	206	219	239	252	272	279	291
150	169	178	191	209	220	240	253	274	281	295
154	173	181	196	213	228	245	254	277	286	304
160	176	182	205	216	235	249	261	278	289	305
307	338	351	365	375	385	392	399	417	430	440
329	339	352	366	376	386	395	400	418	435	455
330	341	353	372	382	387	396	409	419	436	465
334	343	364	373	384	388	397	411	429	438	470
479	503	517	523	564	575	606				
489	510	518	534	568	576					
492	511	520	549	571	578					
493	514	522	553	574	580					

2. Salt Fallout

27	156	575
75	160	576
76	288	
154	561	

a. Wet Fallout

5	30	90	561
9	43	197	
12	52	227	
20	53	285	

b. Dry Fallout

5	172	528
9	202	561
17	227	604
51	249	

c. Impaction

62  
160  
184  
572

d. Incrustment

62  
184

3. Salts in Water

12	7'	303	404
18	221	305	406
46	224	363	545
57	248	403	

a. In Oceans

26	58	105	180	238	325	466	563
35	69	138	215	263	326	515	599
37	78	152	224	287	439	531	600
56	104	179	226	293	456	542	601

b. In Rivers

3	71	137	340	487
19	73	148	474	516
24	103	158	478	570
29	126	210	486	602

c. In Lakes

2	15	64	182	203	226	234	312	349	403	459
3	59	79	191	210	230	237	321	354	427	509
4	60	103	192	211	231	264	340	370	448	516
14	63	139	201	225	235	266	348	401	458	521

558  
366  
581  
598

d. Chemical Composition of Water

3	20	73	86	105	157	230	312	349	403	450
14	29	81	101	106	181	237	321	362	421	451
15	60	84	103	119	182	263	340	363	443	465
19	64	85	104	148	221	266	348	401	448	474
478	509	558								
482	516	566								
486	521	602								
487	555									

4. Salts in Ice and Snow

16	32	178	208	259	313	324	361	374	546
20	37	198	227	297	314	346	364	396	552
25	77	199	257	307	315	356	365	399	565
27	134	207	258	310	323	357	366	510	

5. Salts in Soils

17	71	100	144	191	254	266	383	457
19	91	106	151	200	255	311	401	543
41	98	125	154	201	264	348	405	547
66	99	139	157	240	265	362	421	570

6. Salts in Groundwater

83	101	137	173	363	427	451	487	547
84	103	139	182	371	434	465	516	555
86	119	157	223	383	448	482	543	556
99	126	158	312	401	450	486	545	

7. Salt Content of Rocks

317  
478  
595

8. Salts on Roads

464

9. Salts, General

3	207	237	332	425	456	497	525
74	208	288	399	426	457	498	567
80	212	292	402	432	466	515	580
106	226	308	404	452	467	519	581

10. Distribution, Areal

a. World

17	103	225	287	391	498
75	151	234	293	453	526
76	153	238	309	454	527
78	154	264	390	466	

b. North America

26	42	89	131	153	177	196	227	233	247
27	79	110	132	154	178	201	230	239	248
29	87	111	134	173	184	211	231	245	249
32	88	113	139	176	191	224	232	246	252
260	285	315	324	401	458	516	561		
266	286	316	328	427	459	545			
267	310	321	354	449	476	555			
272	314	323	371	451	507	556			

c. Central America

343  
523  
553

d. South America

e. West Indies

28  
249

f. Europe, including USSR in Europe

(1) Europe

6	30	40	116	128	137	142	148	157	164
8	33	62	119	129	138	145	149	158	165
9	38	73	126	130	140	146	153	159	179
19	39	93	127	135	141	147	154	163	180

182	195	213	218	277	353	376	380	436	503
183	202	214	250	304	362	377	381	437	605
192	207	216	270	330	374	378	382	438	
193	208	217	276	352	375	379	409	465	

(2) U.S.S.R. in Europe

3	36	66	83	99	130	213	217	404
5	56	78	84	101	137	214	218	430
13	57	80	85	118	138	215	306	431
35	58	81	86	128	192	216	309	472
473	606							
474								
547								
604								

g. Asia, Including USSR in Asia

(1) Asia

2	90	228	259	348	385	397	414	418	486
21	97	243	289	372	386	400	415	439	502
24	188	257	295	373	387	405	416	441	511
60	203	258	307	384	388	412	417	470	514
517									
518									
528									
602									

(2) U.S.S.R. in Asia

59	90	128	485
60	117	138	487
78	119	221	517
82	125	223	531

h. Africa

10	143
67	153
100	154
121	334

1. Australia and New Zealand

4	98	220	455	520	570
12	112	240	482	534	571
63	200	253	499	535	
64	219	254	500	558	

j. Antarctica

14	77	265	365	510	566
15	129	346	366	521	
16	181	361	370	546	
27	227	364	403	565	

k. Atlantic Ocean Area

389  
390  
391

l. Pacific Ocean Area

11	133	160	392	501	592
47	135	172	415	574	596
52	144	274	477	578	
53	150	278	500	591	

m. Indian Ocean Area

369

n. Arctic

37 224  
119 227  
134 531  
176

o. Desert

17	191	243	434	459
87	192	264	441	519
151	201	266	445	556
177	242	421	458	

p. Tropics

10 235  
28  
135  
144

q. Stratosphere

356

11. Vertical-Altitudinal Distribution

87 111 232 283 477  
88 136 271 356 485  
89 156 276 379 577  
110 197 280 437

12. Environmental Elements

55 113 186 439 462 502  
90 135 206 440 466 518  
91 143 254 449 472 574  
111 151 377 452 485 595

a. Temperature

322

b. Precipitation

53 206 228 295 532 575 591  
91 213 236 329 552 576 592  
196 216 281 341 553 582  
204 217 284 416 573 584

c. Humidity

9  
420

d. Moisture

82 127  
83 475  
97 476  
117

e. Wind

59	111	453	591
65	113	454	605
66	398	462	
110	418	577	

f. Hail

186

g. Frost

353  
374  
438

h. Vegetation

70  
71  
112

13. Bursting Bubbles and Jetting of Particles

35	49	115	359	389
45	55	165	507	
46	61	296	579	
48	114	358	585	

14. Chemicals

a. Sodium

61	135	477
77	144	495
103	152	564
106	343	

b. Chlorine/Chloride

20	57	103	116	133	152	169	196	249	261	308
21	61	106	127	134	153	174	206	250	267	309
22	77	110	131	135	154	175	213	251	289	310
34	102	113	132	136	159	184	235	260	301	317
323	328	341	400	468	485	548	606			
324	331	354	435	475	517	549				
326	338	376	446	477	526	550				
327	339	382	447	484	544	568				

15. Corrosion

9	161	325	331	461	508
10	162	326	350	476	524
33	232	327	362	480	541
108	250	328	460	494	

16. Design Criteria

,5  
76

17. Electrical Charge

42	49	273	481
45	57	296	
46	61	415	
48	109	461	

18. Experimental Data

18	34	74	241	315	422	530	583	603
21	40	120	296	342	423	538	586	
22	44	125	303	402	424	557	587	
25	54	204	308	406	440	572	597	

19. Historical

1	104	190	309	399
2	105	226	348	489
90	149	290	382	599
98	183	301	393	600

20. Instrumentation

23	318	447	496	548	569
132	367	471	504	550	588
262	413	490	506	559	593
274	431	495	529	560	

21. Maps

75	146	183	353
76	147	249	542
116	151	285	
141	154	293	

22. Particle Size

111	186	273	381	435	469	539	589
135	188	316	391	436	526	575	
169	256	337	412	446	527	576	
176	270	380	419	468	532	581	

23. Processes

65	80	97	115	126	152	179	398	420	469	522	554
66	83	106	120	137	154	180	402	423	470	532	575
68	93	107	122	138	155	185	404	444	484	537	581
69	96	114	125	151	164	362	410	452	485	544	584

595

596

601

24. Radioactive Salts

172

239

281

463

25. Saline Water Conversion

74

26. Salt Chambers and Tests

31 524

108

109

189

27. Techniques/Analytical Methods

7	41	106	131	142	168	174	184	244	284	332	384
23	57	108	132	149	170	175	189	257	290	344	386
27	81	109	136	153	171	181	204	273	296	345	402
31	102	125	140	160	172	183	222	274	306	378	413
423	436	468	488	505	513	546	559	593			
431	442	469	490	506	529	548	560	594			
433	443	475	491	511	533	550	567	596			
435	447	481	503	512	536	551	588	603			

28. Theoretical Considerations

18	44	68	153	179	199	282	386	586
25	54	120	154	190	243	294	398	587
36	56	125	155	197	275	300	562	
40	58	152	156	198	279	301	583	

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13. ABSTRACT <p>This bibliography provides more than 600 references covering all phases of the sea-salt cycle: the origin of the particles in salt lakes, playas, and oceans, the processes by which the salt particles are jettied into the air from sea and lake surfaces by bursting bubbles, their transport inland over the continental landmasses, their impingement, incrustment, and fallout either as dry salt particles or in various forms of precipitation, and their eventual return in rivers to the sea. Selected references are also included on the historic development of the subject, methods of chemical analysis, and techniques of instrumentation and experimental research leading to the formulation of current theories and postulations.</p> <p>An Index to Subjects is included so that the reader may quickly locate references pertaining to his immediate interest. Most of the current meteorological and geophysical journals as well as obscure sources of world-wide scope have been used in this compilation.</p>			

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Salt Water	1		10			
Atmospheric Diffusion	10					
Atmospheric Corrosion	4		8			
Engineering Standards	4					
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